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OPERATING PRINCIPLE OF THE AUTOMATIC ELECTRONIC pH-METER (SGV-287)

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Several experimental research projects are being conducted in the Laboratory of Automatics of the All-Union Scientific Research Institute of Water Supply, Hydrotechnical Construction, and Engineering Hydrogeology (VODGEO) for the purpose of finding suitable designs for automatic pH-meters with glass electrodes. An ordinary DC vacuum-tube voltmeter circuit, with compensation for the quiescent plate current, was used as a first approximation.

The voltmeter consists of a glass electrode, a Morton flask, a calomel semielement, an amplifying tube, a recording galvanometer (SG-287), filament, plate and grid-bias batteries, and a switch with spring mechanism. The Morton flask with the glass electrode and the two calomel semielements comprise the transmitting element of the set.

Tests with various amplifying tubes (SB-147, SB-154 and SB-112) established the linear relationship between the AC component of plate current and the pH value of the investigated buffer solutions. These tests showed that the SG-287 recording galvanometer, manufactured by the Heat Control ("Teplokontrol'") Trust can be used successfully for measuring pH values providing it has a one-tube DC amplifier built in or added to it. The accuracy of the instrument during the tests was better than 0.1 pH over a range of 1.5 to 8.0 pH.

Compensation for the quiescent plate current of the amplifying tube can be supplied in several ways. In this case, the filament battery of the tube (connected in opposition) was used with a rheostat for setting the compensation voltage.

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If the circuit has provision for visual indication, then, before the pH value is recorded by the SG-287 galvanometer, it is first necessary to establish the electrical zero point by means of the rheostat.

Any cause of instability in instrument operation will produce "creep" in the electrical zero and, consequently, errors in the readings. For example, the SGV-287 readings were found to vary over a wide range when the filament current of the amplifier tube was not stabilized. Each tube was found to have an optimum filament current for stable operation. The filament current could be stabilized in a number of ways, e.g., batteries.

Naturally, the SGV-287 pH-meter is also affected considerably by fluctuations in plate and screen-grid voltages on the amplifying tube. To assure stability (and to avoid the dynatron effect), the screen-grid voltage should not be more than one third the plate voltage. At this optimum value, tests show that the grid current approaches zero, which is the essential operating principle of the SGV-287 instrument.

In regard to the glass electrodes, it is well known that their resistance may vary from about 0.5 megohms to 100 and even 1,000 megohms, depending on the type of glass, their dimensions (particularly, thickness), and the temperature. The temperature coefficient of glass is negative and, according to handbook literature, approximately equal to 3 percent.

In preliminary research to increase the sensitivity of the SGV-287 pH-meter, the so-called magnesium glass electrode (66 percent SiO_2, 6 percent MgO, and 28 percent Na_2O) was used. It has a low electrical resistance -- an electrode with a bulb diameter of 50 millimeters has a resistance of 2.5 megohms at 40 degrees centigrade and 0.45 megohms at 34 degrees centigrade. The change in resistance from 4 degrees centigrade to 27 degrees centigrade is nearly linear, but above 27 degrees centigrade it levels off asymptotically at about 0.44 megohms.

Best results with the SGV-287 pH-meter were achieved at 35 degrees centigrade, at which point the electrode resistance is almost constant and comparatively small. At lower temperatures there was a marked variation in the resistance, the temperature coefficient being 3.13 percent for magnesium glass.

If grid current of the tube is present in the glass electrode circuit, it is quite natural that a voltage drop occurs due to the internal resistance of the glass electrode. Therefore, when this resistance is altered by temperature, a considerable change occurs in the voltage on the control grid. This results in unstable operation of the apparatus. In practice, the glass electrode resistance should be about 0.5-1 megohm and the grid current should not exceed $1 \cdot 10^{-9}$ ampere.

When there is no grid current, the change in temperature of the glass electrode does not affect the stability of operation of the SGV-287 pH-meter. When grid current is present, it is necessary to construct special temperature-compensating devices for "automatic" preheating of the investigated liquids to temperatures at which the resistance of the glass electrode is stable.

Stability is not the only consideration in assuring that the SGV-287 pH-meter operates without grid current. The fact is that the so-called potentiometric (compensation) method of measuring small electromotive forces and voltages depends on the total absence of grid current in the measuring circuit.

Therefore, under these conditions, the proposed simple DC vacuum-tube recording voltmeter has all the advantages of the potentiometric method. In comparison with the better foreign-made pH-meters and potentiometers, (Bristol-Beckman, Fisher, Micromax, etc.) the above-described instrument is reportedly simpler and cheaper.

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